

RESULTS OF A ROCKET EXPERIMENT DESIGNED TO MEASURE DIURNAL VARIATION OF ATMOSPHERIC OZONE

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ABSTRACT

The rocket-borne ozonesonde, developed by the Atmospheric Sciences Laboratory, White Sands Missile Range (WSMR), N. Mex., has been deployed for the study of diurnal variation of ozone in the stratosphere and mesosphere. Five ozonesondes were rocket launched in January 1968 within a 24-hr period, and the data obtained showed ozone variations between day and night above the main ozone peak (22 km). The ozone concentration in the upper stratosphere increased during the night and decreased during the day. A significant decrease in the ozone concentration was observed after sunrise. A Mast electrochemical ozonesonde was also flown during this 24-hr period to compare the data from the two systems in the region of overlap.

1. INTRODUCTION

The presence of ozone in the atmosphere results from a combination of processes involving photodissociation and recombination. Molecular oxygen present in the mesosphere and upper stratosphere undergoes dissociation into atomic form due to solar ultraviolet radiation. The atomic oxygen, in turn, combines with the molecular oxygen to form ozone, which is further dissociated by solar radiation into molecular and atomic oxygen. These processes attain an equilibrium in the daytime when solar radiation is constantly incident upon the earth's atmosphere; but at night, when solar radiation is denied, photochemical equilibrium is disturbed, resulting in the increase of ozone concentration since there is no photodissociation process (Hunt 1966).

There have been few nighttime measurements of ozone absorption because of the absence of a strong ultraviolet source in the night sky; however, a few measurements have been made, particularly in the mesosphere, using moon or night airglow as a light source (Mikirov 1965, Carver et al. 1966, Reed 1968). These measurements have shown an increase in the ozone concentration during the night as compared with the measurements made during the day.

A rocket-borne ozonesonde based on the chemiluminescent principle has been developed by the Atmospheric Sciences Laboratory, White Sands Missile Range (WSMR), N. Mex. (Randhawa 1967). This instrument is ejected from a small meteorological rocket (ARCAS) in the mesosphere and measures ozone concentration while descending on a parachute. The output signal is transmitted on a carrier frequency of 1680 MHz and received at the ground by AN/GMD-1 equipment.¹ Since the instrument does not require a radiation source for ozone detection, it can be used at any time of the day or night.

¹ Mention of a commercial product does not constitute an endorsement.

This paper gives the results of an ozone study (24-hr) made close to the winter solstice at WSMR (32° N.), constituting the first concentrated effort to measure the diurnal change in the ozone concentration in the lower mesosphere and stratosphere.

2. INSTRUMENT

The rocket-borne ozonesonde (Randhawa 1967), a self-pumping device, is shown in figure 1, along with an extended nose cone used in its deployment. It consists of three main parts: power supply, sample bottle including photomultiplier tube and chemiluminescent detector, and telemetry circuit. The air passage has been redesigned (Randhawa 1968) and is now made from black plexiglass with the length of the inlet being decreased considerably to decrease the resistance to the air flow. The weight of the instrument is 2.5 kg. The ozonesonde is calibrated before launch by the use of an ozone generator with known ozone concentration and flow rate.

3. EXPERIMENT

This study was undertaken to observe in detail the ozone distribution from 60 km down to the surface during a 24-hr period. Ozonesondes were deployed at 1750 and 2200 MST on Jan. 8, 1968, and at 0635, 1015, and 1515 MST on Jan. 9, 1968. All instruments produced data, although the rocket vehicle of the 1515 MST January 9 sounding did not reach the desired maximum altitude. A Mast ozonesonde was launched on a balloon on January 9 at 1340 MST from the same site to compare the ozone distribution at corresponding levels derived from the two systems.

4. RESULTS AND DISCUSSION

The results of the soundings (hereafter referred to as numbers 1-5) are shown in figures 2 through 6. Sounding 1

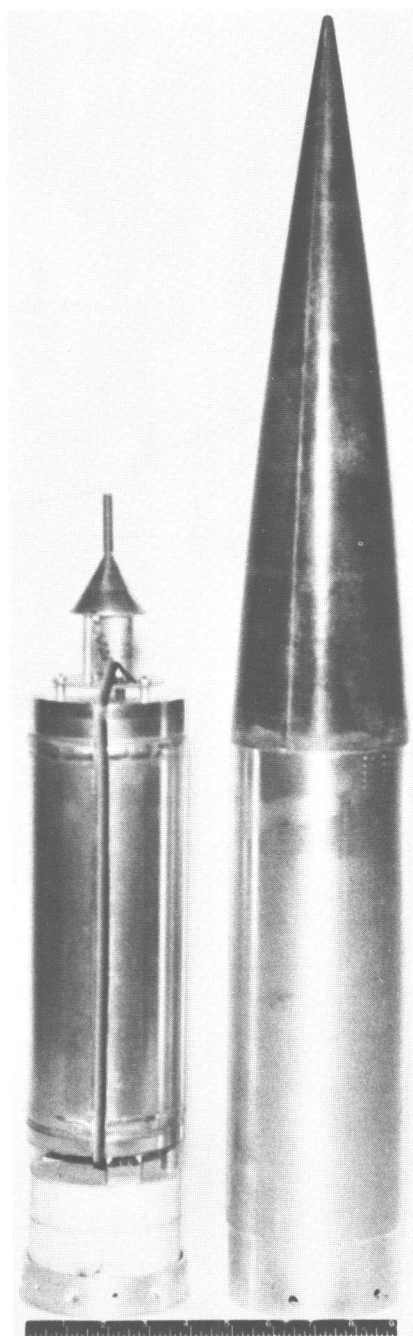


FIGURE 1.—Rocket-borne ozonesonde and extended nose cone.

was near sunset, and sounding 3 was near sunrise. The times calculated for the sunrise and sunset were for an altitude of 50 km. The ozonesonde utilized in sounding 3 was ejected in sunlight but entered the earth's shadow at 42.5 km and registered a marked increase in ozone concentration at that point.

The distributions below the main ozone peak (22 km) agree fairly well with the distributions obtained from the balloon sonde during this period; however, there is a possi-

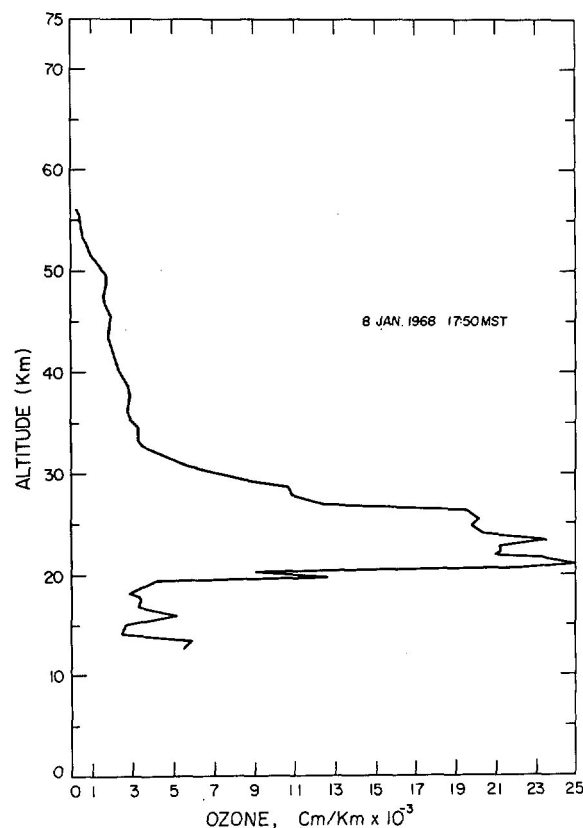


FIGURE 2.—Ozone distribution over White Sands Missile Range, N. Mex., on Jan. 8, 1968, at 1750 MST.

bility that ozone concentration above the main peak may have undergone some diurnal effect. Table 1 gives the ozone concentration measured at different altitudes by these soundings. Photochemical theory based on a moist atmosphere (Hunt 1966, Leovy 1969) does not predict any diurnal change in ozone concentration at these levels, but arbitrary assumptions concerning the rate constants and the possible inadequacies in the reaction scheme have not yet been resolved.

Ozone calculations are based upon knowing the flow rate into the reservoir at different altitudes and calibration constant obtained at the ground before the flight. This flow rate depends upon the differential pressure, which in turn is calculated from the temperature profile obtained from a nearby rocket sounding. The response of the sensor is instantaneous, and it is not sensitive to other oxidants which may be present in the upper stratosphere. It may be sensitive to atomic oxygen, but the possibility of its destruction before it comes in contact with the sensor is very high. The entrance path to the sensor is made long due to its zigzag structure and is made of plexiglass. The reservoir is made of aluminum which destroys atomic oxygen on its contact with the outer surface. The uncertainty in these observations is evaluated mainly on two factors, that is, flow rate and calibration, and is estimated to be of the order of ± 10 percent. The

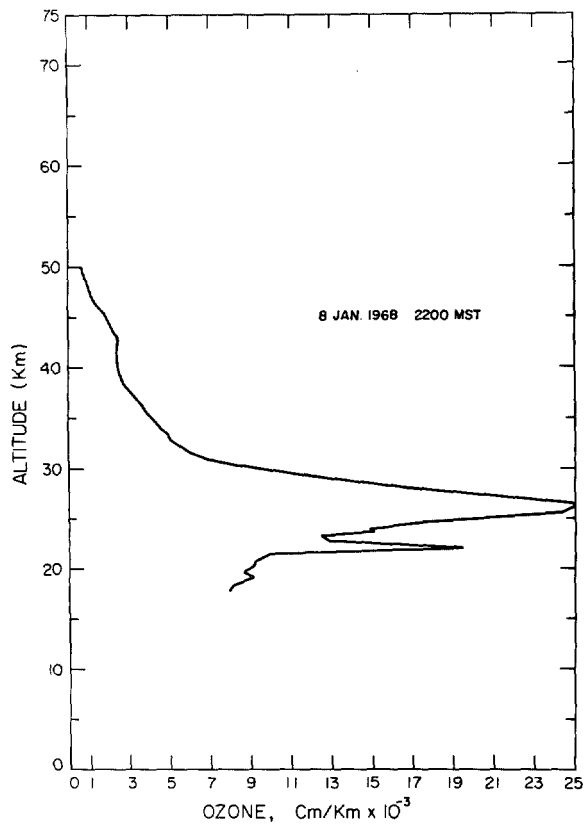


FIGURE 3.—Ozone distribution over White Sands Missile Range, N. Mex., on Jan. 8, 1968, at 2200 MST.

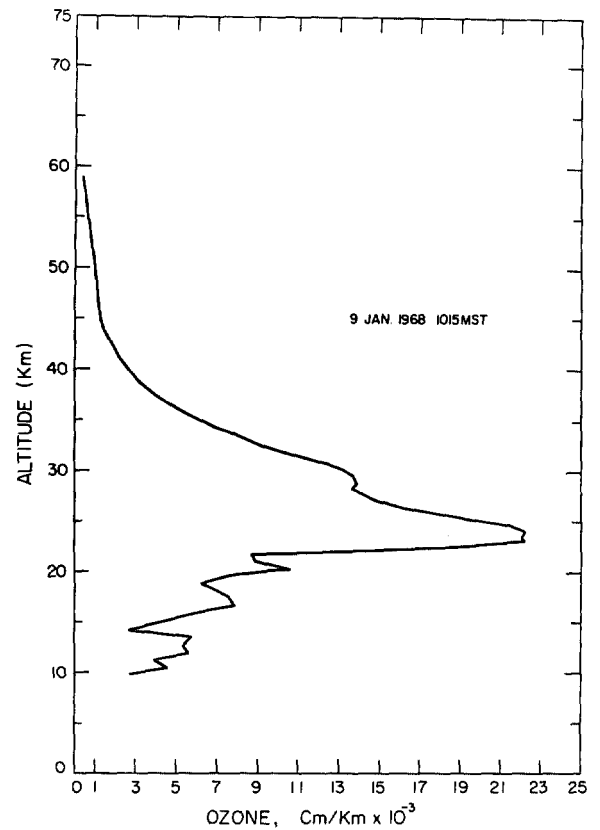


FIGURE 5.—Ozone distribution over White Sands Missile Range, N. Mex., on Jan. 9, 1968, at 1015 MST.

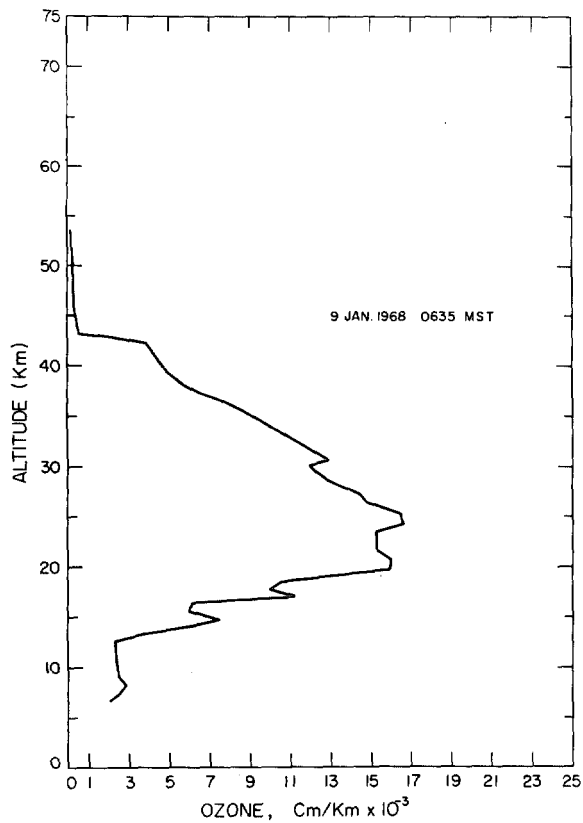


FIGURE 4.—Ozone distribution over White Sands Missile Range, N. Mex., on Jan. 9, 1968, at 0635 MST.

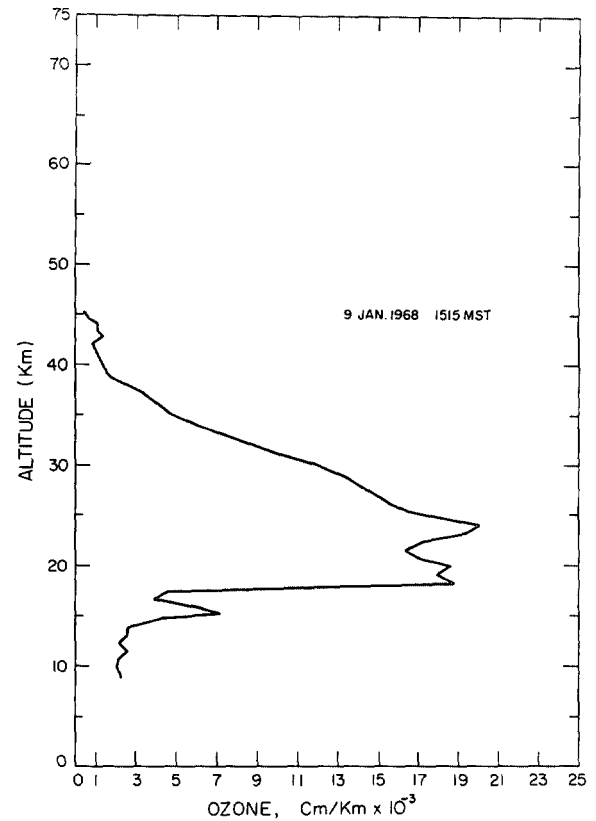


FIGURE 6.—Ozone distribution over White Sands Missile Range, N. Mex., on Jan. 9, 1968, at 1515 MST.

TABLE 1.—Concentration (10^{-3} cm/km) of ozone at different altitudes

Altitude (km)	Jan. 8, 1968		Jan. 9, 1968		
	1750 MST	2200 MST	0635 MST	1015 MST	1515 MST
20	10.5	9.0	16.0	10.6	18.5
25	19.8	21.5	16.6	20.5	17.5
30	7.0	9.5	11.9	13.4	12.0
35	3.1	4.1	9.2	6.2	4.8
40	2.4	2.5	4.7	2.6	1.3
45	1.9	2.0	0.5	1.2	0.7
50	1.6	0.8	0.3	0.9	----

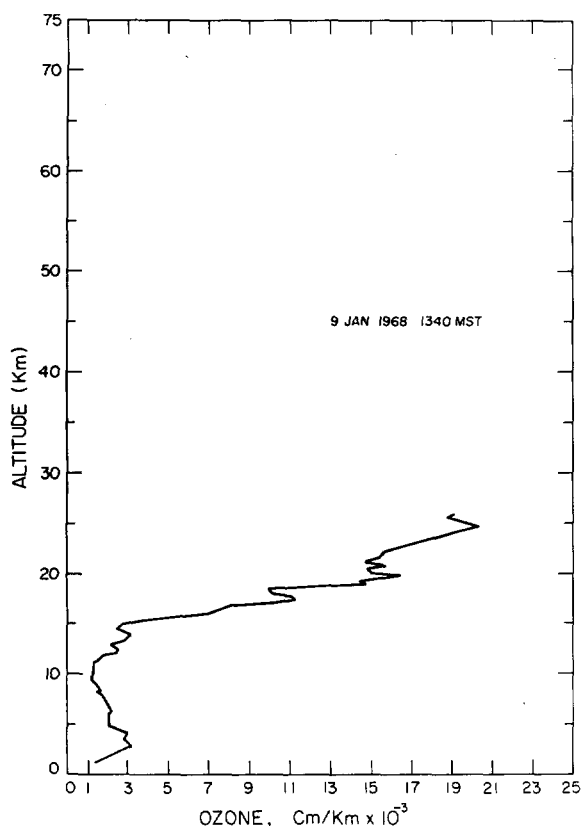


FIGURE 7.—Ozone distribution over White Sands Missile Range, N. Mex., as obtained by Mast ozonesonde on Jan. 9, 1968, at 1340 MST.

error in the flow rate could approach 10 percent, and the error in calibration is significantly less than 10 percent.

Ozone variations measured in the lower stratosphere and troposphere are of greater magnitude than the uncertainties involved and are possibly due to meteorological conditions.

During this period of observations, an almost stationary arctic cold front extended from western New Mexico southward into Mexico. High pressure centered in Illinois

with an additional high in Utah and California. A weak, closed low center in Northern Mexico drifting slowly eastward, caused overrunning of the cold air at the surface in the area, and was responsible for a light snow. Surface winds were light and variable, increasing to 50 kt at 16 km from the southwest on January 8 to 70 kt at 12 km from the northwest on January 9.

No measurements of the total amount of atmospheric ozone above the site were taken with Dobson's spectrophotometer, but the integrated ozone obtained from these profiles agrees with the total ozone measured at Albuquerque (35° N.) near noon on January 9. The total integrated amount from these soundings is 282, 299, 350, 326, and 313 m atm-cm, respectively, whereas the value at Albuquerque was 326 m atm-cm. Agreement is generally good between the balloon data (fig. 7) and rocket data, even when no total ozone value is available.

5. CONCLUSIONS

This diurnal study made near the time of the winter solstice has shown ozone variation in the upper stratosphere. The ozone concentration increased during the night and decreased during the day. This being the first study of this type, it is difficult to make other than qualitative conclusions. Additional studies of this type are planned for different latitudes and in different seasons.

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